CHAPTER – II

THE GEOLOGICAL HISTORY OF THE GREAT BARRIER REEF

Quotation

"Coral reefs are probably the oldest living communities in the sea, perhaps older than any extant terrestrial biomes." (Joel Hedgpeth, "Treatise on Marine Ecology and Paleoeconomy," 1957.)

Introduction

Australia is an island continent with an extensive tropical coastline. Its western shores mark the southeastern margins of the Indian Ocean while, to the east, it provides the southwestern boundary of the Pacific Ocean. Between these two is a complex, poorly known, northern coastline which runs close to southern Indonesia, separated by the Timor Sea to the west and the Arafura Sea to the east.

After Indonesia, Australia has the largest area of coral reefs of any nation, nearly 50,000 square kilometers, or some 19 percent of the world’s total area of reefs. Conditions for reef development vary considerably along the coastline. In the far west the climate is dry and there is little terrestrial runoff. Reef development is not continuous, though away from loose coastal sediments there are important areas, including Australia’s best developed fringing reefs. The southward flowing Leeuwin Current is also important on this coastline, bringing warm waters to relatively high latitudes and enabling the development of some unique reef communities. Further north there are several reefs on the outer edges of the continental shelf. These include remnants of what may have been a substantial barrier reef structure drowned as a result of rising sea levels over geological time scales. The northern coastline is less known, but however this is an area of high terrestrial runoff, and the waters are shallow and turbid, greatly restricting reef development. The
eastern boundary of the Arafura Sea is marked by a narrow constriction, the Torres Strait. East of here, the world’s largest coral reef complex commences, extending out to the margins on the continental shelf and continuing southwards as the Great Barrier Reef. The warm, southward flowing East Australia Current also supports the development of high latitude reefs along Australia’s eastern shores to the south of the Great Barrier Reef. Other reefs are found in Australia’s offshore waters. Most notable among these are the extensive reef structures of the Coral Sea, east of the Great Barrier Reef.

Australia also administers the Cocos (Keeling) Islands and Christmas Island in the Indian Ocean, both of which have significant coral-reefs. Australia’s original human population, the Australian Aborigines, are thought to have inhabited the country for more than 40,000 years. These people, and the Torres Strait Islanders who occupy parts of the far northeast of the country, have traditionally made considerable use of reef resources. It seems likely, however, that their overall impacts remained minimal. Population densities were low, and a large area of offshore reef remained inaccessible to them.

The continent was first described by European travellers in the 17th century. Dampier visited parts of the northwestern coast in 1688 and 1699. Captain James Cook was the first to navigate the waters of the Great Barrier Reef, and indeed ran aground there in 1770. The first British settlement was established in Australia in 1788.

The Aboriginal population has decreased considerably since European occupation, while many of those who remain have been dispossessed of their traditional lands and have ceased to practise their traditional lifestyles. A few remaining coastal populations still have considerable rights regarding their traditional use of the reefs, but their numbers are so low that they are unlikely to have any significant impact except, perhaps, in parts of the Torres Strait region. The dominant human
impacts can now be related to fisheries and terrestrial runoff from deforestation, overgrazing and certain agricultural practices. Compared with most countries, however, these impacts remain few. Population densities are low in all coral reef areas, while the location of many reefs at some distance from the shore further protects them from human impacts.

Considerable resources have been put into coral reef research in Australia and, despite the vast area of reefs in the country, there is a good deal of information describing their distribution and biodiversity. Equally importantly, the great majority of Australia’s reefs fall within protected areas. The Great Barrier Reef Marine Park is the largest protected reef in the world, and is well managed with a detailed zoning plan, providing areas of strict protection alongside much larger areas of multiple diversity.

In order to understand the history of the Great Barrier Reef, we need to have a full knowledge of its geological history and formation, for it is very hard, if not impossible, to understand all aspects of the reef without it. The Great Barrier Reef, compared with other reefs in the Pacific Ocean, is comparatively young and is still forming. When Captain James Cook was on his first voyage to Australia on his ship the H.M.S. “Endeavour” together with Joseph Banks, who led a team of scientists, his ship struck hard coral on the night of 11th June, 1770 and it cut through the ship’s bottom almost immediately. This was the first contact of science with the Great Barrier Reef and the point of contact was named Endeavour Reef. It was only 43 years before this time that Andre’ de Pleyssonnel (1727) had told the scientific world that coral polyps were animal organisms and not plant organisms as was previously thought. The Royal Society of London took a further 24 years to accept this fact.

The Great Barrier Reef occupies most of the north-eastern Australian continental shelf and it extends through 15º Latitude north to 24º South for about 2,300 kilometers. It covers an area of 240,000 square kilometers of which 43,000 square kilometers contain the main zone of
reef development accounting for 85% of the 2,500 individual reefs which occur within the province.

The above diagram shows the interaction between reef, energy level, grazing intensity and nutrient level.

The Great Barrier Reef encloses the world’s largest carbonate province and was destined to be in the forefront of scientific research. It began its recent history approximately 12,000 to 15,000 years ago during the post–Pleistocene advance of the sea over the Queensland continental shelf. Prolific growth of Calcareous algae, coral, as well as skeletal debris led to the formation of numerous reef masses because of the favourable hydrological conditions and shell structure in this region of the South West Pacific. In comparison with other reef provinces of the Pacific, the Great Barrier Reef is young and there is evidence that new reefs may still be forming. An essential part of the natural processes of physical agencies are storm waves, heavy rain and earthquakes, together with biological attacks from carnivorous and boring organisms. More than 90% of the
reef mass consists of detrital material. (Detritus – Geology, an accumulation of small fragments such as sand or silt worn away from the rock). The future of the reef will be determined primarily by sea level movement, climatic variation and tectonism. Most of the more than 220 rocky islands are composed of ancient metamorphic and igneous rocks. Some large islands are formed of sandstone. There has been substantial reef growth in the northern and central areas of the reef but less in the southern region. Also in addition to the rocky islands there are about 60 low islands called cays which are small islands of reef – derived from gravel and sand resting on the main reef mass. They rarely exceed 1.0 km2 in area.

In addition to Captain James Cook’s discovery of the Great Barrier Reef in 1770, additional voyages of discovery and scientific collecting have also taken place. The German botanist Adalbert von Chamisso (1781-1838) circumnavigated the globe between 1815 and 1818 on a Russian ship the “Ruric”, and as well as this voyage, two voyages by French scientists Quoy (1790-1869) and Gainmard (1796-1858) also took place. Chamisso in 1821 observed that corals grow towards the surface and appear to flourish best in the surf zone, which on mid-oceanic prominences, will in time produce a ringlike form with an ever widening lagoon where, because of a lack of food for corals, erosion may predominate. On the “Uranie”, Quoy and Gaimard made two long voyages reaching the Western Australian coast near Shark Bay in September 1818. They then sailed around the northern and eastern coasts of Australia to Sydney. In 1825 they published a paper which indicated that corals can grow only in shallow water and mentioned that volcanic foundations underlie many atolls, the original water giving the ringlike or annular form to its appearance. Between 1825 and 1828, Frederick William Beech (1796-1856) was commissioned by the British navy to concentrate on the Pacific, mainly in the area of the Bering Straits, to
discover new atolls and reef ringed islands. He was the captain of H.M.S. “Blossom” and later became President of the Royal Geographic Society. The second half of the nineteenth century and early twentieth century was a period that saw the beginning and early development of many fields of study now incorporated within geomorphology.

Over the same period, investigations were made into the erosion and exposure of limestone terrains, and this discovery led to developed discussions as heated as those over Darwin’s Coral Reef Subsidence theory. Simultaneously, ideas were evolving on changing sea levels and after the significance of these for coral reefs, the ideas were recognized by Belt, Upham and Penck. At the same time, great minds dwelt on the problem of their origin and major controversy raged and even today some ideas remain unsettled. With the growth of Marine Sciences in the 20th century, and particularly the progress of Marine Biology, attention was diverted from the more contentious issue of origin to the more objective analysis of reef communities in terms of their faunal composition and of the factors controlling such composition. Expeditions in the early part of the 20th century to the Bahamas, Florida, Caribbean Sea and Great Barrier Reef Provinces provided the wealth of biological and hydrological information that is still in the process of assimilation.

**Origin of the Great Barrier Reef**

The Great Barrier Reef is situated off the eastern coast of Queensland in relatively shallow waters rarely more than 6 metres deep. This is the world’s largest coral reef province, and it extends over an area of 230,000 square kilometers from the Gulf of Papua along 2,300 kilometers of the Australian coastline to just beyond the Tropic of Capricorn. Over 2,100 individual reefs make up the main barrier, with a further 540 high continental islands closer inshore having a significant role. Single coral reefs may cover an area of over 100 sq. kilometers. They are massive structures that have been built almost entirely by
marine plants and animals. The natural composition of the reef is made up of calcium carbonate, the limestone derived from the surrounding waters made by the reef organism. The living reef forms merely a veneer, adding new limestone to these massive structures at rates that can be annually measured in kilograms for every square metre of the reef’s surface.

*The below figure shows the Tectonic Evolution of Queensland State, Australia*

Corals are probably the most obvious life forms of the reefs. Their intricate and colourful shapes are colonial structures made up of thousands of individual polyps, each secreting a small cup of coral limestone. Not surprisingly, until the middle of the 18th century, corals were regarded as plants, not animals. However, these flower–like creatures provide the building blocks for reef construction. Plants are also important in the development of the system, as many secrete limestone. Corraline algae in particular, form cementing crusts that act as mortar for the coral bricks. Innumerable other plants and animals also contribute,
forming fine sand and coarser skeletal material which ends up as either sediment on the reef surface or as infill in the many cavities that develop within the reef. Coral reefs have existed in the earth’s shallow seas for a long time probably in excess of 450 million years, a clear indication of how successful a life form they are. Although the original corals, called rugose corals, became extinct about 200 million years ago, the reefs they formed were probably very similar to modern coral reefs. The scleractinian corals that succeeded the rugose forms probably evolved in the warm waters of the Tethys Sea, a massive ancient ocean which originally existed between the northern European and Asian landmasses and the southern African and Indian continents. It was eventually closed by the gradual Northward migration of the southern continents, a process known as continental drift. The closing of the ancient sea was earliest in the west and latest in the east, so that the evolving corals were slowly pushed eastwards into the shallow peninsula islands which studded the seas of the Western Pacific. It is this area, which has by far the greatest diversity. Over 500 corals species are known in this region.

The Great Barrier Reef is thus relatively young, having started to grow probably no more than 18 million years ago, with many parts little more than one million years old. However, this was a period of great environmental fluctuation in the earth’s history. Sea levels in particular have oscillated from positions slightly higher than present to at least 15 metres below the present level. Corals and associated life forms were able to survive these massive environmental changes and this is indicative of how resistant to natural disturbances this ecosystem is. The coral reef has a very high order of internal organization, greater even than the tropical rainforests of the adjacent humid landmasses, with which coral reefs are frequently compared. Both environments receive high levels of solar radiation, the ultimate source of all ecosystem energy.
The above figure shows the main Tectonic of Queensland and the adjacent of oceanic region during the Paleozoic, Maesozoic, and Cainozoic. The degree and direction of movement of the various elements are indicated by arrows on the cross sections.

Geographical distribution of coral reefs in the world

A new estimate of the extent of the world’s coral reefs by United Nations experts has revealed that they are not nearly as extensive as previously thought. Only 28,400 sq. kilometers exist in 0.01% of the globe’s oceans and widespread degradation has occurred particularly in the last five years. Reefs are “over fished, bombed and poisoned”, smothered by sediment and choked with algae that thrive on nutrient–rich sewage and fertilizer runoff.

Indonesia has the most extensive coral system with an area extending over 51,000 square kilometers (18 percent of the world’s coral). Australia comes next with 49,000 square kilometers (17 percent). The Philippines, Malaysia and New Guinea between them account for about 45,000 square kilometers (about 16 per cent) and the great biodiversity in their system is found in this region, with 500 to 600 species of fish found in each nation’s sector.
The figure above shows the systematic sections which are generalized structural and sedimentary geometry beneath (a) the northern Great Barrier Reef, (b) the central GBR and (c) The Queensland Plateau. (After Davis, et.al. 1989).

It is disastrous that reefs in this most diverse region are the most threatened by human activities. In Indonesia, 82 per cent of the reefs are
at a serious risk, mainly from the blasting method of fishing which they regularly use. This method stuns the fish so that they float on the sea surface and are easily collected, while structural damage to the reef and its ecology is completely ignored.

Australia cannot afford to be complacent about its reef sedimentation. Global Warming is a strong enough threat with those threats being recognized by a report put out by the Great Barrier Reef Marine Park Authority, which found that pollution levels have increased by 1,500 per cent in the last 150 years. Pollution, discharged into the lagoonal waters that lie between the coast and the reef, shows that sediment loads have increased by 300% to 900%; phosphate discharges are up by 300% to 1500%; total nitrogen is up by 200% to 400% and pesticides and heavy metals are now detectable in tidal sediments. Tourist activities also cause much damage.

The diagram below shows the geographical distribution of Coral Reefs in the world.
The above diagram shows some major characteristics of reef ecosystems through time. At the top, the arrows show the major mass extinctions while stars indicate second mass extinctions. Below is the diversity curve for marine families.

**Reef distribution in the South – West Pacific**

There are nine major reef provinces in the South–West Pacific, viz:

i. The Great Barrier Reef Province,
ii. The Eastern New Guinea Province,
iii. The Solomon Islands Reef,
iv. The Coral Sea Platform Group,
v. The Chesterfield Group,
vi. The New Caledonia Province,
vii. The Fiji Province,
viii. The Tonga Province,
ix. The New Hebrides – Santa Cruz Province.
The sequence in which the major provinces have been listed above may be regarded as one reflecting decreasing density and area of reef development – the most concentrated, most extensive reef growth is found in the Great Barrier Reef Province and the least in the New Hebrides–Santa Cruz Province. All of the Provinces are located on major oceanic rises and ridges or on the Continental shelf (Maxwell, 1968).

The Geographical regions of the Great Barrier Reef

Inspite of its complexity, the geographical distribution of reef types does provide the basis for regional data of the Great Barrier Reef province. Major regions and their characteristics are:

Region 1: Torres Strait

This region of large level surf reefs, rises from shallow water and probably from shallow pre–Holocene foundations. The region is very sharply defined on its eastern side.

Region 2: Inner Shelf–Cape Grenville to Cape York

Extending northwards across the midshelf zone opposite Torres Strait, radiocarbon evidence dates from the southern end of this region, suggesting that the modern sea level has been achieved 6000 years before the present level (B.P.). The region is dominated by medium – sized reefs and partially infilled lagoonal or planar type reefs.

Region 3: Largely a shelf edge zone from the Gulf of Papua almost to Cairns

Including the full sized width around Cape Direction, and near the Cooktown region there is an outer fringe of ribbon reefs extending as far north as Cape Grenville, and the outer limits are then being maintained by small planar reefs. Radio carbon dates from at least the southern half of this region, suggest that the modern sea level was achieved close to 6000 years B.P., even on the shelf edge. However, behind the ribbons, reefs are poorly developed, with large karst banks, including many reefs in their early stages of development. Such reefs would probably be the result of
retarded growth rates, initially due to turbidity in the shallow shelf. Submerged, and later due to restricted circulation and slow growth in the lee of the ribbons, pre Holocene platform depths in this area are not deep.

The map below shows the geographical regions of the Great Barrier Reef based on reef distribution.
Region 4:  Inner shelf centered on Princess Charlotte Bay

This area has evidence that not only the modern sea level of today was achieved, as early as 6000 years B.P. (before the present) but relatively slightly higher levels aided in the production of planar reef tops. Shallow foundations of the reefs, possibly including non reefal platforms in Princess Charlotte Bay have also helped to produce senile reefs, including a large number of low wooded island reefs.

Region 5:  Total shelf width - Cairns to Townsville

This area has been shown to have slightly deeper pre Holocene foundations and a relatively late date (Circa 2,500 years B.P.) for the attainment of the modern sea level, and both factors possibly result from long term subsidence. Consequently most reefs are juvenile and mature early, as for example, the “resorbed” reefs of Maxwell. All reefs tops are young (< 2,700 years) in this area.

Region 6:  The major reef tract from Townsville to opposite the Whitsunday Islands

At least in the northern part of this region the modern sea level was achieved by 60,000 years B.P., but it may have been progressively later towards the south and there is a suggestion of some shelf subsidence opposite the Whitsunday Islands, possible in line with an extended Hillsborough Basin. Large medium reefal platforms are present but mainly in the juvenile or early mature stage, suggesting relatively deeper foundations away from the reef rims.

Region 7:  Shelf margin of the Central Great Barrier

Probably subsidence and slow growth combined to give the shelf edge an extremely poor reef development. Submerged reefs and reef patches of medium and small sizes are found here. They may be especially numerous in the uncharted areas of the Pompey complex.

Region 8:  The Pompey Complex

Situated on a structural high this area has the bulk of the Great
Barrier Reef’s large reefs. Large reefs also dominate the western section of the Pompey Group, the centre of which has a number of medium-sized reefs of all types. It is known that the modern sea level was achieved by at least 4000 years B.P. in this area. Where surveyed, pre-Holocene antecedent platform depths are only moderate.

**Region 9: Swain Reef**

South of the Pompey T-line, large reefal platforms are entirely absent. Instead, the Swain Reefs have great numbers of medium-sized and small reefs of lagoonal or planar types.

**Region 10: The Bunker Capricorn Group**

This distinct reef province has mostly medium-sized reefs in late stages of growth. Antecedent platform depths are not deep and the sea level was achieved by at least 5000 years B.P and was possibly higher than at present. These factors, combined with Davis and Marshall’s (1979) evidence of relatively rapid growth rates, appear responsible for the late stages of reef morphology. However, numerous submerged reefs are also found in this area, possibly a legacy of the marginal position of this area for coral growth, particularly early in the Holocene era when deeper reefal platforms were first being submerged. Although some control on the distribution of reef types is given by variation in Holocene sea level depths of antecedent platforms together with variations in growth rates, it is suggested that the major control is that determined by structure.

**Geomorphology of the Mainland Coast of the Great Barrier Reef**

The geomorphic evolution, particularly in terms of sea levels, climate and neotectonics, is of particular relevance to the reef evolution of the Great Barrier Reef. A study of geomorphology of the mainland coast provides us with the knowledge of the consequences through runoff, together with a source of sediments and freshwater both of which may provide major restraints on reef growth and mineral nutrients that enter...
the biological food chain of the continental shelf. The eastern coastal zone of northeastern Australia is backed by a nearly continuous main scarp varying in altitude of up to 1,611 metres in Mount Bartle Frere near Innisfail, with numerous residual or fault – block coastal hills and ranges, the majority of which are aligned parallel to the regional NNW – SSE structural trend.

The coastline is generally parallel to this trend and, apart from comparatively short stretches, such as near Cape Conway, south of Cairns, and around Cape Tribulation, is separate from the main escarpment by a coastal plain of mostly Quaternary sediments, varying in widths of up to 50 kilometers. Where the coastline cuts across the regional structural trend, wider coastal plains are associated with embayed coastlines, as, for example, behind Princess Charlotte Bay, in the Townsville to Bowen area and around Broad Sound.

The origins of the eastern coastal escarpment and subparallel coastal ranges have been a matter of debate for almost 100 years. Hypotheses range from the disruption of a duricrusted Tertiary land surface, a warping of this land surface along meridionally aligned flexure axes to differential erosion of lithologic and structural units of the Tasman Geosyncline. It is probable that all three mechanisms are involved in the formation of the physiography of the coastal zone of eastern Queensland. Lithologic control of relief appears widespread with granites and volcanoes generally forming the upland areas. In the Ingham area, the physiographic units are independent of lithology. In the Prose-pine area, on the margins of a Hillsborough Basin, fault lines clearly control the Corridor systems.

The main earth movements, whether faulting or warping, have long been regarded as Plio – Pleistocene in age, being in the last epoch of the Tertiary period of the Cenozoic era after the Miocene era. These movements were part of the tectonic events that affected the whole of
Eastern Australia and termed the Kosiusko Period by Andrews (1910). Ollier (1977, 1978) has reviewed more recent evidence of landscape evolution including the isotopic dating of basalts extruded during the uplift period. This indicates that the uplift of the eastern highlands, and by analogy the subsidence of the continental shelf, commenced well before the Pliocene era. Some scientists think that the movements may have commenced even in the Mesozoic age and that the last major uplift took place in the Oligocene age which was the third epoch of the Tertiary period of the Cenozoic era after the Eocene and before the Miocene. The series of rocks were formed in this epoch. There is some evidence to suggest that movements took place well into the Cenozoic and possibly into the Quaternary era, and it is suggested that Quaternary adjustments have taken place along the faults of the Whitsunday area. Although regarded as aseismic, earthquakes have been recorded in the Tasman geosynclinal region and it is not unreasonable to assume that small movements may still be taking place. If volcanic activity is considered as synchronous with uplift, then the evidence for earth movements extending into the Quaternary Age is even more convincing. Cenozoic volcanic activity commenced about 70 million years ago in eastern Australia, and continued into the Quaternary age with episodes in each volcanic region lasting about 5 million years. In North Queensland, radiometric ages of basalts indicate major eruptions during the Pliocene Age together with the younger flows and pyroclastics (fragments of volcanic origin which are probably little more than 10,000 years old). Eruptions have certainly taken place in the coastal zone during the evolution of the Great Barrier Reef. The Pleistocene Pyroclastics of Moa, Badu and adjacent islands in Torres Strait contain occasional limestone fragments. An offshore volcanic centre is also preserved at Stephen’s Island in the Barnard Group near Innisfail, and several Scoria (porous, cinderlike fragments of lava) cones in the Cairns to Innisfail area and between Gayndah and Biggenden.
are almost certainly Quaternary in age. Not only do these volcanics suggest that earth movements have been active during even the latter phases of the evolution of the Great Barrier Reef, but there is a strong possibility that volcanics may be interbedded with reefal limestones in some areas.

The table below shows the processes and characteristics of facies in modern reef complexes. (After Longman, 1981)

<table>
<thead>
<tr>
<th>Facies</th>
<th>Process of sedimentation and Controls on organisms</th>
<th>Type of Organisms likely to be preserved</th>
<th>Grain size</th>
<th>Sorting</th>
<th>Amount of Framework</th>
<th>Typical Depth (m)</th>
<th>Domian Rock type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagoon</td>
<td>Low energy, much burrowing, sporadic current and turbidity, possible terrigenous influx</td>
<td>Molluscs, echinoids, milliolids, forams@, ostracods</td>
<td>Mud mixed with coarse skeletal debris</td>
<td>Poor</td>
<td>0%</td>
<td>5-30</td>
<td>Wackestone</td>
</tr>
<tr>
<td>Back-reef sand</td>
<td>Sporadic storms and ocean currents across reefs, salination, gravity sliding</td>
<td>Halimeda, milliods, minor red algae, sparse finger corals</td>
<td>Coarse</td>
<td>Moderate to good</td>
<td>0%</td>
<td>1-10</td>
<td>Grainstone</td>
</tr>
<tr>
<td>Reef-flat</td>
<td>Sporadic storms, good current circulation, winnowing of mud</td>
<td>Finger corals, red and green algae, larger (benthic) forams, head, corals</td>
<td>Coarse-very coarse</td>
<td>Moderate</td>
<td>0-10%</td>
<td>1-3</td>
<td>Scattered corals</td>
</tr>
<tr>
<td>Reef-crest</td>
<td>High wave energy, constant turbulence, good water circulation</td>
<td>Wave resistant corals and algae</td>
<td>Very Coarse</td>
<td>Moderate to good</td>
<td>0-80%</td>
<td>0-2</td>
<td>Grainstone (minor bounds)</td>
</tr>
<tr>
<td>Reef framework</td>
<td>Good water circulation, high wave energy sporadic at greater depths</td>
<td>Abundant corals, algae, molluscs, echinoderms, forams</td>
<td>Framework and sand</td>
<td>Poor, Mud in some cavities</td>
<td>20-80%</td>
<td>1-3</td>
<td>Boundstone</td>
</tr>
<tr>
<td>Reef-slope</td>
<td>Limited light, sporadic turbulence, gravity transport of reef debris</td>
<td>Soft corals, flattened coral plates, sponges</td>
<td>Mixed</td>
<td>Poor</td>
<td>5-40%</td>
<td>20-50</td>
<td>Packstone boundstone</td>
</tr>
<tr>
<td>Proximal talus</td>
<td>Sporadic turbulence, gravity transport, little light, unstable substrate</td>
<td>Few living organisms</td>
<td>Medium to coarse</td>
<td>Poor to good</td>
<td>0%</td>
<td>40-100</td>
<td>Grainstone packstone</td>
</tr>
</tbody>
</table>
Distal talus | Quiet water, no light, gravity with sliding of sediments | Planktic forams | Fine | Moderate to good | 0% | 100-200 | Packstone

@ Foraminiferan (Foram)-any of the unicellular microorganisms of the order “Foraminifera” characteristically having a calcareous shell with perforations through which numerous pseudopodia protrude.

The Evolution of the Great Barrier Reef

In the last thirty years great advances have been made towards understanding the way in which reefs have evolved, particularly when ideas from other coral reef areas are added to those developed solely on the Australian scene. An idealized evolution for a shelf reef over the last 125,000 years can be divided into nine stages:

1. **125,000 years** - The development of coral reefs with morphology similar to reefs of today took place over older coralline limestone foundations to a sea level about 5 metres higher than that of today. These reefs in turn have formed the foundations for Holocene reefs (of a recent geological epoch) and their upper surfaces are generally 10 metres below the modern sea level. This in the result of both erosion and shelf subsidence at a rate of about 0.12 m/1000 years. This rate was used as a basis for all further stages of reef development subsequent to 125,000 years.

2. **105,00 years** - After a lower sea level which allowed the first weathering and diagenesis of the 125,00 year reef, an interstadial transgression resulted in the formation of small fringing reefs to about 14 metres around the older reef core. At this stage the surface of the 125,000 year old reef had been lowered by about 2 metres of Caliche, that is, the crust or formation of calcium carbonate on soil or sand developed over the surface of the outer rim, but some solutional deepening of the old lagoon, may have taken place.
3. **84,000 years** - A lowering of the sea level from 105,000 years to 84,000 years resulted in more weathering and alteration. The 125,000 year old reef had been lowered by about 5 metres and the 105,000 year terrace by 2.5 metres. Sea level at 84,000 years was about -20 metres and any new fringing reef that developed may have been less than 3 metres lower than the outcropping 105,000 year old reef.

4. **60,000 years** - The recurrence of a -20 metres sea level during this interstadial transgression probably resulted in the integration of both earlier interstadial terraces into a single morphological feature. By this time, the 125,000 year reef had been lowered by almost 8 metres, the 105,000 year terrace by 5 metres to -20 metres and the 84000 year terrace by 3 metres. Thus a -20 metres sea level would have transgressed over both earlier terraces, adding a very thin veneer to them and building outwards to produce what should have been a very significant morphological feature.

5. **40,000 years** - This complex interstadial period probably resulted in the extension of the circa -20 metre terrace as the sea probably reached this level for a short period. At the very least it may have provided a further veneer to the 60,000 year old terrace, which in the intervening period, would have been lowered by about 2 metres. In addition a further terrace at about -40 metres was probably added to the reef. By now, the older 125,000 year old reef was at a level of about -5 metres relative to the present sea level. Minor karst landforms (limestone topography) had possibly developed, reinforcing the original constructional morphology. The rise and fall of the sea level had produced migration of the unsaturated area between the earth’s surface and the water table. This is referred to as the
vadose zone which occurs in the unsaturated area between the earth’s surface and the water table in the same way that the phreatic zone refers to the characteristic of water in the saturated area just below the water table (Latin vadosus-shallow, vadum-a ford) (Greek-phreat-a well + English - ic). Because of this, the alteration of at least the 125,000 year old limestone was probably advanced.

6. **18,000 years** - At this lowest sea-level stage, the reef would have completely emerged as a limestone hill on an extended coastal plain. A deep vadose zone existed allowing the enlargement of any pre 125,000 year old cave system on larger reefs. Without the support of water it is possible that a few older cave systems collapsed, producing the saucer-shaped or shallow funnel-shaped hallow in the sea bed, formed by the dissolution of limestone. During the Holocene transgression, these dolines were to become blue holes.

7. **9,000 years** - By now the 125,000 year old reef had been lowered to almost-10 metres to the modern sea level. The compound terrace which had formed at -20 metre levels (the latest round 40,000 years) sank to almost -24 metres and the -40 metre terrace to about -44 metres. The sea level at 9,000 years B.P., was about -20 metres and had risen rapidly to this level. Minimal reef growth had possibly taken place on the deepest terrace but flooding of the compound terrace had commenced and probably resulted in luxuriant reef growth. The oldest reef core remained as a low limestone island, but it too was to be submerged within 2,000 years.

8. **6000 years** - Modern sea levels had been achieved but the rate of transgression had left behind the upward growth of reefs. The reef crest was several metres below sea level, probably
growing at the maximum possible rate with a further distinctive terrace about 15 metres below it. Blue and solutionally deepened ancient lagoons were submerged and being colonized by Holocene reef organisms.

9. The present day - Over the last 6,000 years, reefs have reached the modern sea level and vertical growth has been converted into lagoon filling and horizontal growth has grown on the leeward side. Growth from the compound terrace has also reached sea level on most reefs adding to the horizontal extent of reef floors. Where growth has been slower, Holocene construction from this terrace and possibly from the deepening ancient fringing reefs may be just reaching the modern sea level forming a distinctive line of outer reefs beyond the main reef front. Where external reef flats have formed, deposition of rubble on the reef margins and sand on the lee side, has resulted in island formations. Locally, the moating of water levels behind shingle ramparts or algal rims has led to the deposition of a final, slightly higher veneer of coral laid down in micro atoll form. Variation in the morphology and size of the reef foundations, and in rates of increased growth and sea level fluctuation during the era of the Holocene, have produced the diversity of reef types found in the modern Great Barrier Reef.

**Geological History of the Great Barrier Reef**

The Geological history of this region is similar to that of the land part of North Queensland until the mid Cretaceous Period and very different afterwards. After the mid - Cretaceous Period there was a multi-phase coastal extension to form the present margin of the Australian continent in the late Cretaceous Paleocene Period. Thick sedimentary sequences were deposited before and during this extension process and later. The Cainozoic deposits include the Great Barrier Reef.
The Framework of the Continental Shelf

The continental shelf is dominated by the Great Barrier Reef, and the continental slope along the eastern margin of the Great Barrier Reef, is steep and incised by Canyons in its northern part, but decreases in gradient in the vicinity of Townsville and becomes gentle, adjacent to the Marion Plateau. The Marion Plateau is the smallest of the marginal plateaus in the Coral Sea region and extends as a terrace beyond the continental shelf. It deepens to a depth from about 200-300 metres in water depth near the Great Barrier Reef, to about 500 metres in the vicinity of the Marion Reef at its northeastern corner. The north-north-west-trending landward margin has a slope with a moderate gradient, extending southwards to approximately 22°S. The Queensland Plateau is the largest marginal plate of the Australian continental margin. Roughly triangular, it lies at an average water depth of 1100 metres. Extensive reef growth occurs on the plateau, particularly along its southern margin. Slopes are generally steep, with extensive canyoning. Its western margin tends north-north west, its north-eastern margin facing the Coral Sea Basin tends northwest, and its southern margin tends east-west. The western and southern margins are both bounded by linear bathymetric longitudes, the Queensland and Townsville Trough respectively. Both the Queensland and Marion plateaus are understood to be underlain by eroded basement platforms composed of early Palaeozoic rocks of the Tasman Fold Belt, with north-north tending lineations.

The Townsville trough has a symmetric U-shape profile, which is maintained over most of its length. Water depths along the central axis vary from 1100 m to 2000 m, deepening to the east where the Townville Trough merges to the southeast into the Cato Trough. The Queensland Trough tends north-northwest and has a relatively smooth floor, which deepens northwards in a step like way from about 1100 m at its junction with the Townsville Trough to a 2800 m at its junction with the Osprey
Embayment. Both the Townsville and Queensland Trough are underlain by rift basins, referred to here as the Townsville and Queensland respectively. Two styles of basin development can be identified along the central part of the northeast Australian margin.

**Pre-Mesozoic (The Geological era before the present era: The Mesozoic Era began about 225 million years ago)**

An ocean drilling programme has been undertaken at various sites in the western Queensland plateau and intersected to prove that these sites consist of deformed metasediments. Also granodioritic (granular, igneous rock intermediate between granite and Quartz - diorite and tonalitic inclusive are intercalated with the metasediments. The presence of these rocks on the Queensland plateau confirms that rocks of the Tasman fold belt are likely to underlie both the Queensland and Marion Plateau. Feary et. al. (1993) correlated these basement rocks with those of the Devonian Hodgkinson formation.

**Middle Jurassic - Early Cretaceous**

The middle Jurassic Age to the early Cretaceous Age intra - cratonic down- warps, contain conformation of clastic rocks deposited in continental depositional environments. Sediment is generally about 1 km thick. The basis of these types are: Papuan Basin, Peninsula Trough/ Torres Shelf and the Laura Basin.

**Cretaceous - Cainozoic Rocks**

Rift Basins - Late Cretaceous and early Tertiary sediments lie beneath the rifted margins of the Australian continent and the adjacent plateau. The basins are particularly thick in the major troughs - the Queensland and Townsville Basins, where Syn- rift thickness is up to 5 km, and sag - phase thickness is up to 4 km. Basins are 70-150 km wide. In the deeper rift trenches the depositional environment of the Syn- rift
and longitudinal rift sediments probably range from continental marginal marine to restricted shallow marine.

The history of a continental shelf is illustrated by a section across the Australian continental shelf off Ingham, 90 km northwest of Townsville (Symonds et. al. 1983). The figure below shows a shelf formed by five deposit sequences as follows:

1. A represents a thin Syn-rift sequence of late Cretaceous-Paleocene age sediments deposited by alluvial stretches and fans.

2. B was an onlap-transgressive phase of the plaeocene and Eocene age, formed during continued thermal cooling and subsidence. Sedimentary environments range from marginal marine fan deltas, through restricted shallow marine, to open marine oozes and turbidity.

3. C resulted from progradational - regressive phases of late Oligocene (P1), Late Miocene (P2), and the late Pliocene and early Pleistocene (P3) age, with progradation of fluvial and wave dominated shelf margin delta sedimentation and regressive phases of marine only faeces.

4. D is a shelf aggradation/ progradation phase of the Pleistocene age (P4), due to concurrent subsidence and deposition.

5. E is a reef development with pro - deltaic sediment on the inner shelf of the Pleistocene - Recent age.

Davis et. al. (1991) published that a section across the Queensland Trough described the sediment complex faulting beneath the central part of the trough, and he thought that to indicate that the extension had a significant slip component. The section contains basement tilt blocks that are westerly, dipping into the Queensland Plateau and in the middle of the trough, are easterly dipping on the margin of the Queensland Plateau. The tilt blocks are overlain by about 8.00 metres of tilted Syn - rift sediments, and planated at the Paleocene "Break up" uniformity, when sea floor
spreading started to the north. Planation is the process of erosion and deposition by which a stream produces a nearly level land surface. (Latin planum-plane + English ation). A basement high in the east- centre to the trough is a feature on other seismic profiles to the north and south. Sediment thickness is about 30.00 metres near the middle of the trough and about 40.00 metres under the western flange. The late rift phase sediments are thought to be shallow marine in the troughs and marginal marine and continental marine on the trough flanks, plateaus and shelves. Paleocene to Eocene sediments are shallow marine in the trough and shelf type on the trough margin. Sagging caused regional subsidence after the middle Eocene. Sediments on the plateau and shelf were made shallow marine after the Middle Eocene. Sediments in the trough are mainly terrigenous and calcareous turbidities in the middle to the late Eocene but are absent because of erosion in the Early Oligocene: since then they form pelagic ooze, turbidites and slump deposits.

Distribution of Reefs in the Continental Margin Structure of the Great Barrier Reef

The major characteristics of the Carbonate platforms determined from extensive geological and geophysical investigations are described by Davis et.al. (1989).

Here the Great Barrier Reef is only 25.0-30.0 metres thick, of Pliocene to Recent age, and is composed of several slices separated of unconformities generated by low sea levels. The reef sits on the uppermost part of a thick coral shelf sequence that is dominated by progressive fluvial deltaic matter and onlapping shelf sediments, overlying a rift basement.

The diagram shows the idealized model for the evolution of shelf reef from the last interglacial to the present.
The basement (Proterozoic rocks) was overlain by pre-rift and syn-rift sediments, block faulted during rifting, and planation took place during the Cretaceous Oligocene era. Most of the plateau was overlain first with shallow water silicic sediments, and then with deeper water pelagic sediments. Subsidence was gradual to the late Miocene, and rapid since then.

The Queensland Plateau has been a carbonate dominated province since the earliest Miocene era. Along the Western margin of the Queensland plateau, steep sided pinnacles of 1-2 km across, rise from depths of as much as 12.00 metres to within 10 metres of the sea level.
Some of these pinnacles have developed on the raised corners of fault blocks. In the Central part of the plateau, a thick carbonate platform sequence has formed. Platform growth was in several phases, each separated by planation. All the Queensland plateau reefs are of a high energy oceanic type.

**Tectonic History of the Great Barrier Reef**

The influence exerted by the mainland on the evolution of the Great Barrier Reef province is one which is not readily assessed. Some indication of its magnitude is gained through the consideration of the geological character of the region and through the examination of its present sediment source potential. The major geological feature in eastern Queensland is the Tasman Geosyncline, which, during its several phases of development from ordovician to Early Triassic time, became the site of heavy marine sedimentation, intensive vulcanicity and organic upheaval. By early Mesozoic times, the belt had achieved relative stability, and widespread freshwater deposition then occurred during this era. Crucial movements continued but they were non orogenic in character and
smaller in scale than the earlier deformations. Similar terrestrial sedimentation, on a more restricted scale, persisted through the Cainozoic era. Again, faulting and block movement were important and widespread volcanic extrusion occurred. The main tectonic framework of eastern Queensland evolved during the Palaeozoic Era and it consists essentially of the various units of the Tasman Geosyncline. Younger features of the Mesozoic and Cainozoic age are significant. Two groups of tectonic elements may be recognised. These are the belts of old metamorphic and igneous rocks which acted as positive elements throughout most of the Palaeozoic and subsequent eras, and the intervening formation of basins of sedimentary rocks. The main positive elements form three sub-parallel. Stratigraphic evidence suggests that seven tectonic episodes occurred during the evolution of eastern Australia.

**Summary of tectonic events on the Great Barrier Reef**
*(after Symonds et al. 1996)*

<table>
<thead>
<tr>
<th>Northeast Australia</th>
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<tbody>
<tr>
<td><strong>Trassic-M. Jurassic</strong></td>
</tr>
<tr>
<td><strong>L. Jurassic-E. Cretaceous (120-150 Ma)</strong></td>
</tr>
<tr>
<td><strong>Barremian-Cenomanian (95-120 Ma)</strong></td>
</tr>
<tr>
<td><strong>Cenomanian (90-100Ma;-95)</strong></td>
</tr>
<tr>
<td><strong>Cenomanian Campanian (80-95 Ma)</strong></td>
</tr>
<tr>
<td><strong>Campanian- Paleocene (60-80Ma)</strong></td>
</tr>
<tr>
<td><strong>Paleocene-Eocene</strong></td>
</tr>
<tr>
<td><strong>Late Eocene-Miocene</strong></td>
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The first tectonic episode involved the downbuckling of the main geosynclinal belt in the Early Paleozoic time and the intensive sedimentation and vulcanicity produced great thicknesses of argillite, greywacke, radiolarian chart and interbedded andesite (Radiolarian- any of various marine protozoans of the order Radiolaria), having rigid siliceous skeletons and radiating spicules forming the soft tissues of certain invertebrates of calcium carbonate growth. Chert-microscopically crystalline mineral varieties of silica occurring in layers of modules in sedimentary rocks. Along the marginal shelf areas, extensive carbonate deposition occurred and major coral reefs developed. The second tectonic episode began after a widespread orogenic disruption during the middle Devonian. As a result of this deformation, uplift, intrusion and metamorphism of the geosynclinal sediments occurred. Positive tectonic elements emerged and new negative belts began to subside, namely the western Hodgkinson - Star Drummond Basins and the eastern Yarool Basin. Deposition of argillaceous and naceous material, largely of volcanic derivation, began at a rapid rate but as tectonism declined, carbonate sedimentation dominated the region and coral reefs developed a topographical pattern that is evident today. The seven tectonic episodes that have been recognised on the mainland must be taken into consideration in any assessment of the development of the continental shelf and adjacent regions. The rest of the main tectonic elements of the Tasman Geosyncline are interrupted quite sharply along the coastline, and the sparse geophysical and geological data suggests that these elements continue on the shelf, and that the submergence of large parts of the shelf has resulted not only from post-pleistocene eustatic changes but from major crustal adjustments associated with the later tectonic episodes recognised on the mainland. Eustasy is caused by world-wide changes in sea level caused by the melting of ice caps, deposition of sediments and similar related phenomena.
Conclusion

There is no Alpha and Omega of the Great Barrier Reef. It began in aeons of time and is still evolving. The Great Barrier Reef is thus relatively young, having started to grow probably no more than 18 million years ago and in many parts it is little more than one million years old. However, this was a period of great environmental fluctuation in the earth’s history. Sea levels in particular have oscillated from positions slightly higher than present to at least 15.0 metres below the present level. The major geological feature in eastern Queensland is the Tasman Geosyncline which, during its several phases of development from Ordovician to the early Triassic time, was the site of heavy marine sedimentation, intensive vulcaninity and organic upheaval. The Queensland Plateau along the Queensland coast, has been a carbonate dominated province since the earliest Miocene era. Along the Western margin of the Queensland Plateau, steep sided Pinnacles 1 to 2 kilometres across, rise from depths of as much as 12.00 metres to within 10 metres of sea level. Some of these pinnacles have developed on the raised corners of fault blocks. In the Central part of the platform a thick carbonate platform sequence forms. Platform growth was in several phases, each separated by planation. All the Queensland Plateau reefs are of a high energy oceanic type. In spite of great scientific research since 1770, there are still no actual results as to the actual origin of the Great Barrier Reef.